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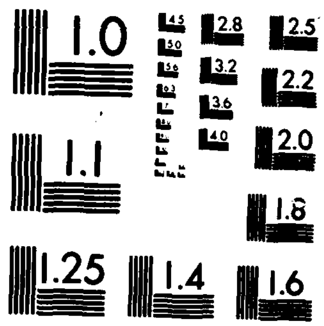

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Population densities of phyto- and zooplankton are inversely proportional. Grazing pressures of zooplankton determine phytoplankton concentrations.

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SEASONAL RELATIONSHIPS BETWEEN PHYTOPLANKTON AND MERO-ZOOPLANKTON POPULATIONS IN THE LOWER CHESAPEAKE BAY, VIRGINIA

By

Harold G. Marshall
Raymond W. Alden III

Final Report
For the period ending December 1984

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Seasonal Relationships Between Phytoplankton and Mero-zooplankton Populations in the Lower Chesapeake Bay, Virginia

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The initial purpose of this study was to identify seasonal patterns of abundance for phytoplankton and mero-zooplankton larvae in the lower Chesapeake Bay. The next objective was to relate the temporal appearances of these two groups to each other and identify any apparent relationships. More detailed reports of the phytoplankton and zooplankton populations from this area have been prepared by the authors under separate titles to the U. S. Army Corps of Engineers. Emphasis in this report will stress, the broad distribution patterns of these species and their trophic relationship to each other in time. Past mero-zooplankton studies in the lower Chesapeake Bay have been minimal and generally stress individual species, their life cycles, distribution, or general ecology, (e.g. Sandifer, 1973; Chanley and Andrews, 1971; Bryan, 1979; and Grant, 1977; among others). Jacobs (1978) noted seasonal zooplankton pulses in the lower Bay, with holoplankters associated with a winter-spring abundance and meroplankton concentrations higher during the summer-fall period. Phytoplankton populations within the lower Bay have been characterized as being composed of net and nanoplankton components, each with characteristic patterns of seasonal growth and changing concentration levels (Patten et al., 1963; Marshall, 1980, 1982; Marshall and Lacouture, 1985; among others). Spring and fall maxima occur and are dominated

by a diatomaceous flora. Dinoflagellates are generally most abundant in summer, however, various pulses are produced during the year by these and other components.

METHODS

This report is based on plankton collections made at four stations located in the lower Chesapeake Bay between February 1982 and December 1983 (Figure 1). Phytoplankton samples were taken monthly at the surface and a depth one meter above the bottom. Standard water bottle casts were made from which 500 ml of water was preserved immediately with a buffered formalin solution. Additional samples were taken at one of the stations and preserved with a modified Lugols solution for comparative purposes. A settling and siphoning procedure followed to obtain a 40 ml concentrate that was transferred to a settling chamber for examination and cell counts with an inverted plankton microscope. Cell volume measurements were determined by corresponding each phytoplankter to one or more geometric forms, obtaining mean measurements, and determining cell volume in μM^3. Zooplankton was collected with single oblique bongo tows, with a 355 μM mesh net, from approximately one meter above the bottom to the surface. Mechanical flow meters were used in each net to calculate the relative volume sampled. Monthly samples were made from October through April, and semi-monthly from May through September. The samples were fixed with a 7% buffered formalin and later examined using a subsampling method with sieve fractions of 2000, 850, 600, and 350 μM (Alden et al., 1982). Salinity and temperature data were obtained with a Beckman RS-5 induction salinometer. Phytoplankton samples were taken the same day as the zooplankton tows.

RESULTS

The temperature patterns for the four stations were similar, with peak tem-

peratures occurring at the surface in July 1982 and September 1983 (Figure 2). However, the 1982 warming trend of summer began earlier and lasted longer in comparison to 1983, before dropping below 20°C in October. Also in contrast, the May 1983 water temperatures were below those of May 1982, resulting in a warming pattern that did not become established till June 1983. Seasonal temperature lows occurred during February-March (1982) and January-February (1983), with another decline in progress at the end of the study in December 1983. Surface temperatures were typically warmer except in winter, when the water temperatures were colder at the surface. The rise in vernal temperatures in 1982 and 1983 were associated with an increase in phytoplankton concentrations and major larval development of several meroplankters. Other meroplankton larvae were present at other times during the year. However, example of both phytoplankton and zooplankton periods of maximum development occurred during periods of rising temperatures (spring) with reductions during periods of decreasing temperatures (fall) for the zooplankton, and winter for the phytoplankton. Bottom salinity values were greater, averaging 21.6 and 25.3 °/oo, respectively for surface and bottom samples (Figure 2).

Seasonal Distribution Patterns of Phytoplankton

The periods of total phytoplankton maximum development were similar at each station in the lower Bay (Figure 3). The collections began during a period of declining cell numbers in February 1982. This decrease continued into May, which was then followed by a slight rise in June. Growth at this time was dominated by small, chain-forming diatoms with cells generally <20 μM. A small decline was also noted in fall followed by a major development that began in mid-winter and eventually became the spring outburst for 1983, reaching maxima during the February-May period. In addition to the small sized diatoms, various non-diatom pico-nanoplankters (<10 μM) were prominent during this growth period. Cell levels began to rise in mid-summer (1983), to form a major fall outburst. This occurred from August through October and was composed of a combination of non-diatom pico-

nanoplankters, cyanobacteria, and several small (<20 μM) centrales diatoms. Although this development was decreasing rapidly into winter, there were indications of another increase in December. Throughout the year, the seasonal concentration patterns at bottom depths were generally similar to the surface. However, there was a trend to have higher concentrations in the bottom samples due mainly to the diatoms. The biomass patterns, depicted by cell volumes, closely followed the seasonal expressions of cell concentrations. Generally, spring and fall maxima were found. However, there were distinct differences in times of initiating and terminating these maxima. Periods of lowest biomass values were generally noted during the summer and early fall. Winter was a period of transition, representing the beginning for the vernal outburst in 1983, and the time for an early development, declining into spring, as indicated in 1982.

In comparing the two years of study, there is a marked difference in productivity levels, with concentrations lower during 1982 in comparison to 1983. This change is mainly due to differences in the pico-nanoplankton component and was most apparent during summer and fall. In a broader study of this region during the same period, similar differences were noted within Hampton Roads and outside the Chesapeake Bay entrance (Marshall and Lacouture, 1985). In contrast, diatom and dinoflagellate values during this 1983 summer were slightly higher than in 1982 (Figures 4,5). There appears to be differences in abundance related to cell size between these two years, with the pico-nanoplankton components (<20 μM) and the cyanobacteria having a marked increase in numbers in 1983. In contrast to this 1983 rise in abundance depicted by mostly the pico-nanoplankton categories, there was no major change in the comparative year patterns of phytoplankton biomass (cell volume). This may be due to the small volume associated with the pico-nanoplankton in standing crop evaluations.

Seasonal Distribution Patterns of Mero-zooplankton

No composite seasonal distribution curves are presented for the meroplankton

in this presentation. Their composition is diverse and represent a variety of life stages, with numerous temporal relationships. From a data set of over 100 meroplanktonic forms, 16 species or categories were selected for review at this time. These are listed in Table 1 in relation to their seasonal patterns of appearance. A significant unimodal pattern of larval release is common to a large number of species in the lower Bay. This period begins approximately in April and extends into late October or early November. This pattern with a fall peak is found in the xanthids, pagurids, *Callinectes*, *Pinnotheres*, *Pinnixa*, *Uca*, and *Anchoa mitchelli*. Possessing a more condensed time frame, *Lucifer faxoni* appears in July, peaks in September and October, then declines into December. Several of these meroplankton species are common through the year but have single periods of annual high abundance. These include *Neomysis americana* which peaks in fall or early winter (August-December). Other species found throughout the year, but with a spring maximum include *Cancer irroratus* (April), *Crangon septemspinosa* (March-April), and representative bivalve larvae (May). Lowest concentrations of larvae were associated with winter, followed by early spring. Highest concentrations were found during summer and fall.

These seasonal periods of peak development are similar to concentrations of holoplankters in marine habitats with increased concentrations generally associated with late spring and summer (Colebrook and Robinson, 1961). Two basic food chains have been suggested for the various phytoplankton and zooplankton combinations by Parsons and Le Brasseur (1970). These would be 1) nanoplankton-microzooplankton-Macrozooplankton, and 2) net phytoplankton-macrozooplankton. The preference for larger phytoplankters (<20 μM) by macrozooplankton has been noted by Mullin (1963), and Durbin and Durbin (1975), among others. Many of these herbivores may also be opportunistic feeding on both net and nanoplankters. Parsons et al. (1969) found *Calanus* spp. mainly grazing on net species (*Skeletonema costatum*, *Thalassiosira nordenskioldii*, *Thalassiosira rotula*), but if necessary

were capable of grazing microflagellates. Raymond and Cross (1942) found *Calanus* capable of surviving on phytoplankton cells of 1-3 μM. Parsons et al. (1967) also noted a nanoplankton (8 μM diam.) could be utilized by *Calanus pacificus*, but was not effectively utilized by *Euphausia pacifica*. The minimum size of particles that may be captured by these adult zooplankters will vary, such as 8-10 μM by *Calanus pacificus*, and 3 μM by *Pseudocalanus* sp., with *Oilopleura dioica* larvae at 0.3 μM (Runge and Ohman, 1982). Joint and Pomroy (1983) indicate only a few calanoid copepods appear capable of filtering particles <5 μM and Mullin and Brooks (1967) found even *Calanus* nauplii and copepodites preferred larger phytoplankters to smaller ones. In studying the feeding behavior of adult Atlantic menhaden, Durbin and Durbin (1975) noted a minimum-size threshold for filtration being 13 to 16 μM, while Scura and Jerde (1977) found anchovy larvae did not feed on cells less than 10 μM in size. Nanoplankton food chains have been closely related to various adult and larval microzooplankton. Capriulo and Carpenter (1983) found nanoplankton less than 10 μM a common food for tintinnids in Long Island Sound. They noted high densities of nanoplankton associated with, but not required for the tintinnids that occurred at the same time. Turner et al. (1983) related seasonal food chains to specific herbivores where nanoplankters were eaten by copepod larvae, copepodites, and ctenophores. The nanoplankton's reduction in concentrations in Monterey Bay was related by Garrison (1975) to selective grazing by microzooplankton and planktotrophic larvae, and horizontal advection from the area. A size preference for nanoplankton (<10 μM) by oyster larvae has also been reported by Fritz et al. (1984) and Mauer et al. (1984). In addition to these various zooplankton components, major phytoplankton concentrations may leave the water column by settling and be utilized by the benthos (Smetacek et al., 1982). In San Francisco Bay, Cloern (1982) related low phytoplankton concentrations and absence of major floral blooms to extensive removal of these cells by suspension feeding by adult benthic bivalves in the Bay.

In addition to the phytoplankton food supply identified for this area, consideration should also be given to other similar sized food particles that would be available to the zooplankton. These would include a variety of detrital substances and organic matter in suspension within the water column, including the passive and high concentrations of fish eggs. Peak periods of abundance for fish was found to be between May and June, the same time of high meroplankton larval concentrations.

DISCUSSION

The periods of high meroplankton production occurred generally between April and October in 1982 and 1983. During this period in both years of the study, there was a corresponding drop in the total biomass (cell volume) of phytoplankton. Phytoplankton cell volume peaks occurred during early spring in 1982, and in the mid-winter-early spring time in 1983, rising again in the following fall. This winter high for phytoplankton biomass corresponded to low concentrations of meroplankton larvae.

Although the floral biomass indicated similar seasonal patterns of abundance for the two years, this was not represented in the total cell counts of the phytoplankton. There was a sharp increase in abundance in 1983 over the 1982 levels. Majors peaks occurred from August through October 1983, coinciding to high larval concentrations of *Lucifer faxoni*, *Neomysis americana*, *Callinectes* sp., xanthid spp., pagurid spp., *Uca* spp., *Pinnixa* spp., and *Pinnotheres* spp. These increased phytoplankton levels were due mainly to pico-nanoplankton cells (<5 μM) that provided high numbers and reproductive potential, but low biomass from the standing crop measurements used in this study. Due to the cell size category they represent, it is not likely that the dominant meroplankters present, or holoplankters expected at this time of the year, were actively grazing down these numbers. There was either less grazing pressure on this particular trophic community, or

the environmental conditions favored a significant increase in the abundance of this group that exceeded what feasibly could be utilized by the micro-herbivores present. Over this time period, concentrations during summer-fall were also greater in 1983 for the diatoms, cryptomonads, dinoflagellates, haptophyceans, and cyanobacteria. Seasonally, concentrations of dinoflagellates usually show greater development during the summer period than at other times of the year, but no significant was noted during this period. In contrast, the cyanobacteria had a significant summer pulse, infering different selective grazing pressures on these two groups. Grazing pressure by holoplankters would be expected to have a major impact on these floral populations and to possess different degrees of intensity through the year. Turner et al. (1983) found during the warmer seasons nanoplankters were the dominant forms involving grazing by the smaller copepod species, nauplii, copepodites, and planktonic coelenterates and ctenophores. In colder waters, net phytoplankton were more common and were mainly grazed by the larger zooplankton and fish larvae.

In summary, the lower Chesapeake Bay supports diverse and abundant populations of zooplankton and phytoplankton. Each of these groups exhibited seasonal patterns of abundance through the two year period of study. A seasonal decrease in phytoplankton biomass coincided to increase concentrations and grazing pressures by the merozooplankton, in concert with holozooplankton populations, in these waters. Low meroplankton concentrations occurred during periods of high phytoplankton abundance. An increase of phytoplankton concentrations occurred during the second year of the study. This may be the product of reduced grazing pressures by the zooplankton, or a surplus floral supply that accumulated in the water column and was left ungrazed. The net and nanoplankton concentrations were never exhausted and appeared to exceed the removal processes throughout periods of maximum grazing demands.

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Table 1. Seasonal pulse patterns of mero-zooplankton larvae in the lower Chesapeake Bay for 1982 and 1983. x denotes presence, A indicates peak periods. No samples were taken in January 1982.

Larvae		J	F	M	A	M	J	J	A	S	O	N	D
Crangon septemspinoso	1982	-	x	x	A	A	x	x	x	x	x	x	x
	1983	x	x	A	A	A	x	x	x	x	x	x	x
Lucifer faxoni	1982	-						x	x	A	A	x	
	1983							x	x	A	x	x	x
Callinectes sp.	1982	-			x	x	x	A	A	x	x	x	
	1983	x					x	A	A	x	x	x	x
Cancer irroratus	1982	-		x	A	x			x	x	x	x	x
	1983	x	x	x	x	x		x	x	x	x		x
Penaeid shrimp	1982							x	x		x	x	
	1983	-									x		
Neomysis americana	1982	-	x	x	x	x	x	x	x	x	A	A	x
	1983	x	x	x	x	x	x	x	A	x	x	x	x
Ammodytes hexapterus	1982	-		-	-	-			x		x		
	1983	x	x	x					x	x			
Anchoa mitchelli	1982	-				x	x	x	x	x	x		x
	1983	x	x				x	A	x				
All Flat Fish	1982	-			x	x	x	x	x	x	x		
	1983	x	x				x	x	x	x			
All Gastropods	1982	-			x	x	A	A	x	x	x	x	x
	1983		x	x	x	x	x	x	x	A	x	x	
Xanthid spp.	1982	-				x	x	x	A	x	x	x	x
	1983	x	x			x	A	A	A	A	x	x	x
Pagurid spp.	1982	-			x	x	x	x	A	x	x	x	
	1983			x	x	x	x	x	x	A	x	x	
Uca spp.	1982	-				x	x	x	A	x	x	x	
	1983		x				x	A	A	A	x		
Pinnixa spp.	1982	-				x	x	x	x	A	x	x	x
	1983	x	x			x	A	x	x	A	x	x	x
Pinnotheres spp.	1982	-			x	x	x	x	A	x	x	x	
	1983						x	x	x	A	x		
All Bivalves	1982	-		x	x	x	x	x	x	x	x	x	x
	1983	x	x	x	x	A	x	x	x	x	x		
Fish Eggs	1982			x	x	A	A	A	A	x	x	x	x
	1983		x			A	x	A	A	x	x	x	

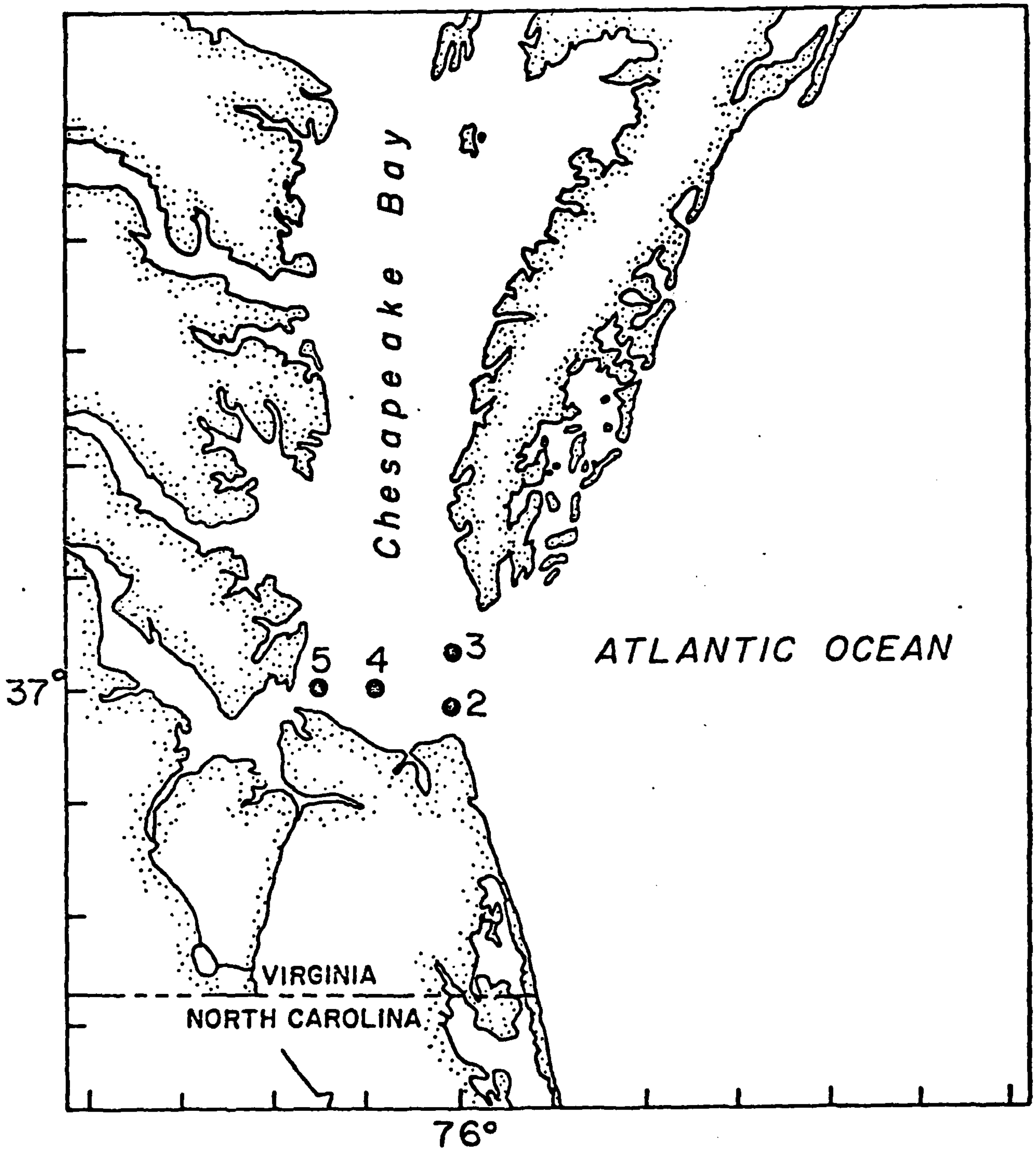

Figure 1. Station locations during the study.

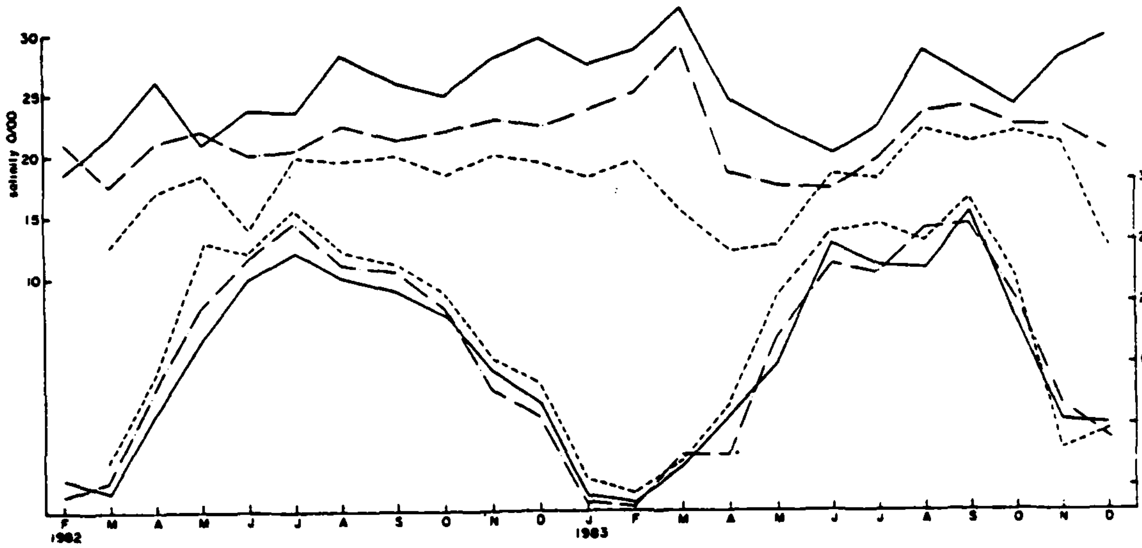

Figure 2. Salinity ($^{o}/oo$) and temperature records during the study for station 1 (———) outside the Bay entrance, 4 (—·—) in the lower Chesapeake Bay, and 7 (----) in Hampton Roads.

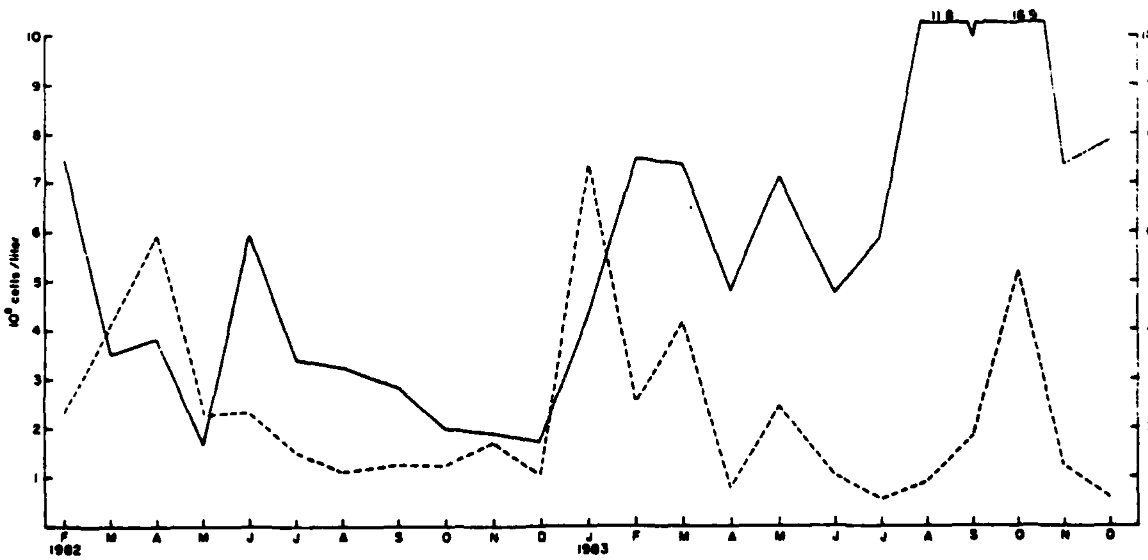

Figure 3. Combined surface and bottom averages for total phytoplankton cell concentrations (———) and cell volume (----).

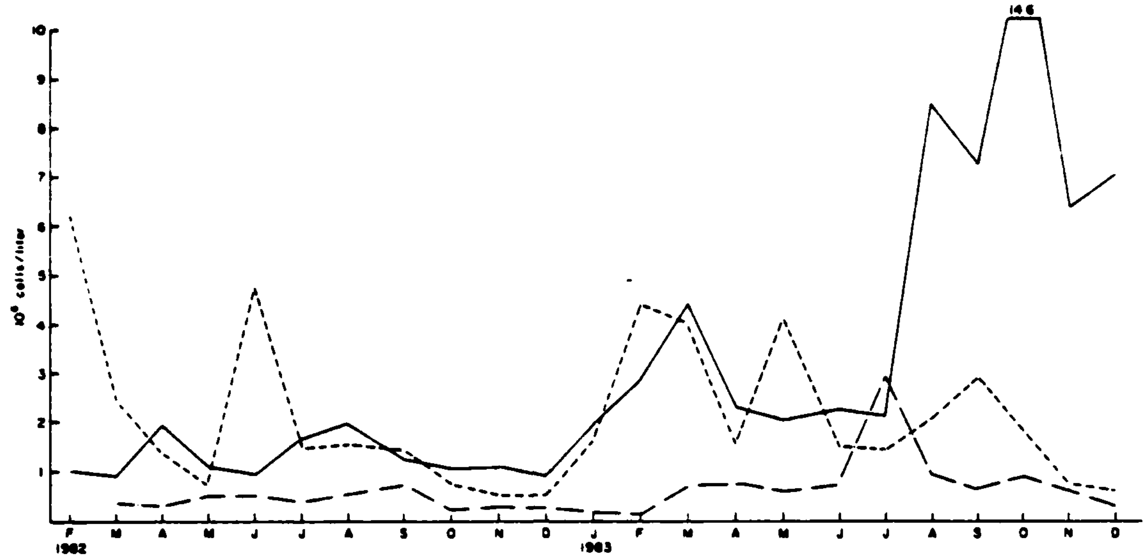

Figure 4. Combined surface and bottom averages for total cell concentrations of pico-nanoplankton (——), diatoms (----), and cryptomonads (-·-·).

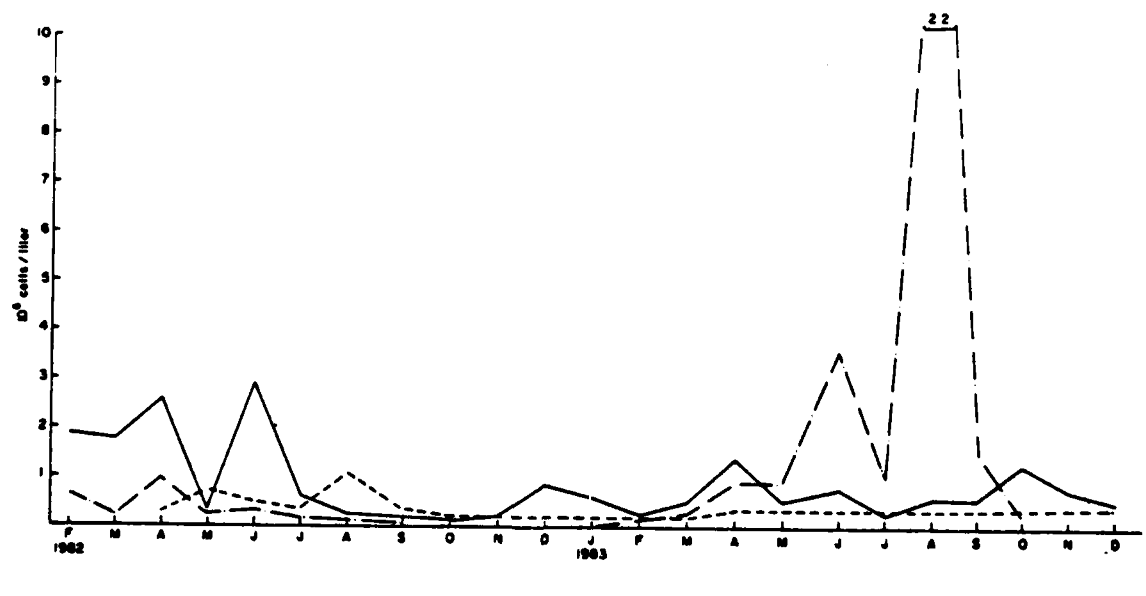

Figure 5. Combined surface and bottom averages for total cell concentrations of dinoflagellates (——), haptophytes (----), and cyanobacteria (-·-·).

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